Spatial Scale of Drought in a Meso-Scale Southwestern Watershed

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INTRODUCTION

Large and intense droughts raise concerns, but equally intense droughts may occur at smaller spatial scales, even when large droughts don't.

Typical rangeland management units are 5-15 km^2, therefore detecting small-scale droughts is critical.

In this study we describe,

- The relationship between small- and large-scale drought, and
- How those relationships differ between winter and summer, drought indices, and since the recent dry period began in 1996.

METHODS

- Data represent the 225 km^2 Santa Rita Experimental Range (SRER) in southern Arizona with 73 y of monthly precipitation records from 22 gauges, temperature from PRISM.
- SRER divided into 100 1.5km*1.5km cells, precipitation interpolated from 22 gauges.
- Summer (Jun-Sep) and Winter (Oct-May).
- Two drought indices: Standardized Precipitation (SPI) and Standardized Precipitation-Evapotranspiration (SPEI).
- Drought defined as the driest 20th percentile (driest 15 y) for each cell (small-scale) and for entire SRER (large-scale).
- Contiguous drought cells define a drought patch (see Fig. 1).

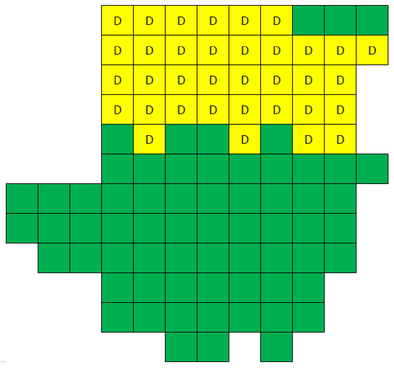

Figure 1. In 2000 summer, the large-scale SPEI is -0.40 (not a drought). However, a large drought patches (yellow cells) of 78.75km^2 occurred SRER.

Large-scale SPI, SPEI and Temperature

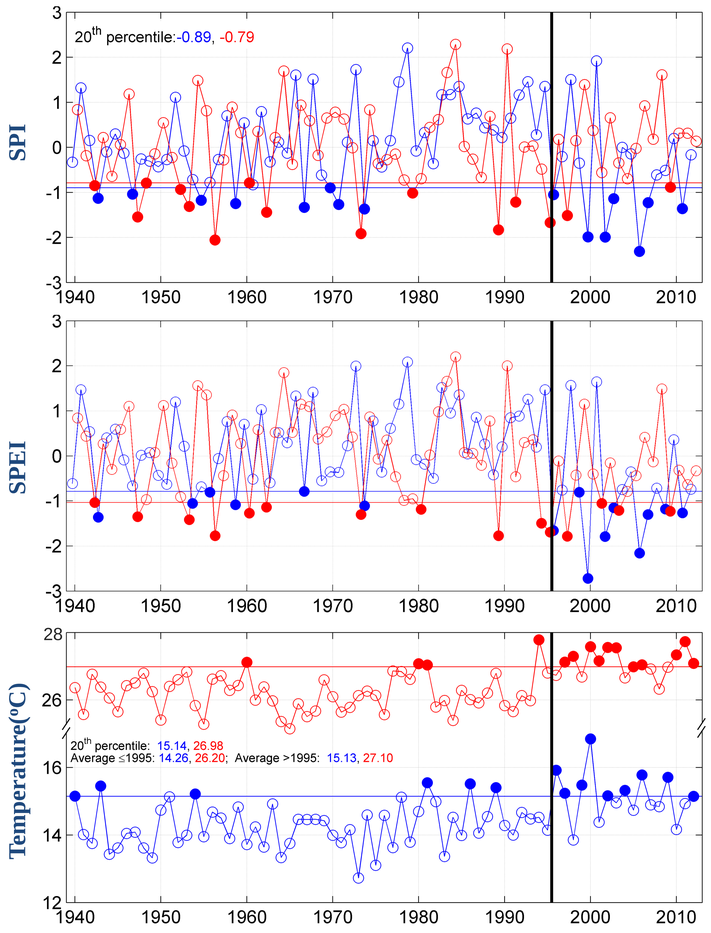

Figure 2. Time series of winter (blue) and summer (red) SPI, SPEI and Temperature from 1940 to 2012. Drought is defined as driest 20th percentile (solid horizontal line) and the 15 drought years have solid circles. For temperature, warmest 20th percentile is identified. Black vertical lines separate the time series at 1996.

Large-scale Drought Frequencies

Table 1. Proportion of years that had 20th percentile drought and warm values compared for years ≤1995 and >1995 at the large-scale (all SRER).

Season	Index	≤1995 (N=56)	>1995 (N=17)
Winter	SPI	0.14	0.41
	SPEI	0.11	0.53
	TEMP	0.11	0.53
Summer	SPI	0.23	0.12
	SPEI	0.20	0.24
	TEMP	0.07	0.65

Small-Scale Drought Patch Size related to Large-Scale Dryness

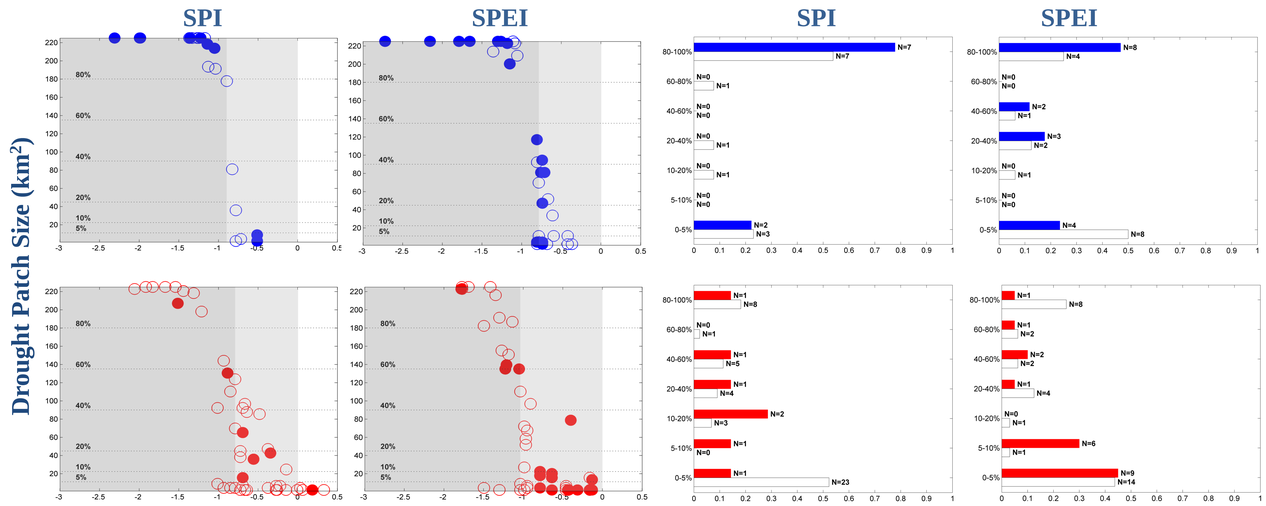

Figure 3. Drought patch size in relation to large-scale (all SRER) dryness in winter (blue) and summer (red), and size distribution of patches compared for years ≤1995 and >1995. Patch size given as km^2 and percent of the large-scale (SRER). Solid dots and bars indicate years >1995. Shading in left-panels identifies dryness at the large-scale: dark grey is drought (<20th percentile), light grey is less than average (mean) but >20th percentile, and white is above average (mean). The 4 panels on the right show patch size distributions (proportion among total patches) among six size classes.

RESULTS

- **Large-scale drought frequencies**

  Drought and warm years were more common after 1995 (41-65% of years) except for summer SPI which was less common (12%) (Tab. 1 and Fig. 2).

- **Large and Small-scale drought relationships:**

  For both winter and summer, drought patches the size of management unit s(5-15 km^2) were very common before the large-scale SRER reached a drought condition. Drought patches occurred even when the large-scale is above average only with summer SPI (Figs. 1 and 3).

- **Small-scale drought patterns: ≤1995 vs. >1995**

  Similar scaling of drought patch size with large-scale average, except for a) <1995 small drought patches occurred in summer (SPI and SPEI) when large-scale is drier than 20th percentile, and b) >1995 more large patches in winter (SPI and SPEI) and increase in management unit (5-15 km^2) patches in summer (SPI and SPEI; Fig. 3).

- **Small-scale drought patterns: SPI vs. SPEI**

  Drought patch size distribution is less uniform using SPI than SPEI in winter, but in summer they are very similar (Fig. 3). Most patchy in summer (SPI=SPEI), and least patchy in winter (SPI<SPEI).

CONCLUSIONS

1. Only in summer, small areas of drought (<10 km^2) can occur when large-scale (225 km^2) conditions are above average because summer monsoon is less spatially uniform than winter cyclonic systems.
2. A greater range of drought patch sizes occurs using SPEI than SPI in winter only, possibly because of the uniform spatial distribution of temperature.
3. The fundamental relationship between small- and large-scale drought patterns changed only slightly since the recent dry period started in 1996.
4. Given these small-scale patterns of drought, we recommend:
   a) For detection -- A dense network of rain gauges, with one gauge per management unit (pasture or water development), and
   b) For management -- Infrastructure (pastures, waters, corridors) and adaptive management designs to avoid small-scale drought patches.

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